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This bulletin, prepared by Dr. Y. Y. Chao, Mr. L. D. Burroughs, and Dr. H. L. Tolman of the Ocean Modeling Branch (OMB), Environmental Modeling Center (EMC), National Centers for Environmental Prediction (NCEP), describes automated wave guidance for waters surrounding Alaska alphanumeric and Gridded Binary (GRIB) formats. This guidance was implemented operationally on the new IBM computer in January 2000.

The Gulf of Alaska (GAK; a second generation) regional wave model was replaced with the Alaska Waters (AKW; a third generation) regional wave model. The AKW is based on the NOAA WAVEWATCH-III (NWW3) which is described in detail in Technical Procedures Bulletin (TPB) 453 (Chen, Burroughs, and Tolman 1999) and Tolman (1999a, b, and c). The NWW3 provides the boundary conditions to the AKW. More specifically, the AKW accounts for wave dispersion within discrete spectral bins by adding in diffusion terms to the propagation equation (Booij and Holthuijsen 1987); it uses the Chalikov and Belevich (1993) formulation for wave generation and the Tolman and Chalikov (1996) formulation for wave dissipation; it employs a third order finite differencing method with a Total Variance Diminishing limiter to solve wave propagation; its computer code has been optimized to utilize the Massively Parallel Processing (MPP) structure of the new IBM R/S 6000 SP computer; it uses a higher spatial resolution (0.50° x 0.25° rather than 30 n mi x 30 n mi), a larger domain (160°E - 124°W by 45°N - 75°N instead of 155°W. - 132°W by 53°N - 61°N), a higher frequency resolution (25 frequencies in place of 20), and a higher directional resolution (24 directions to replace 12).

Various graphics and text products for the AKW are available at http://polar.wwb.noaa.gov/waves/. The following wind and wave parameters are available in GRIB format at the web site above, on Family of Services (FOS), and on AWIPS as GRIB bulletins: Hs, Dm, Tm, peak wave period and direction, wind sea peak period and direction, wind speed and direction, and u- and v-wind components. Note, however, that significant wind sea height, significant swell height, and mean swell period and direction are no longer provided. The peak period and direction replaces the swell period and direction for a large part of the domain.

Spectral text bulletins for the AKW are available at the web site above. These files are in ASCII and are available by anonymous ftp from the directory ftp://polar.wwb.noaa.gov/pub/waves. These bulletins will be implemented on AWIPS as soon as headers can be derived for them. The wave guidance will continue to be generated twice daily based on the 0000 and 1200 UTC cycles of the Aviation (AVN) run of the Global Spectral Atmospheric Model.

Technical Procedures Bulletin No. 427 is now operationally obsolete.

LeRoy Spayd
Chief, Training and
Professional Development
Core

U.S. DEPARTMENT OF COMMERCE **National Oceanic and Atmospheric Administration**

WAVE FORECASTING FOR ALASKAN WATERS

By

Y.Y. Chao, L.D. Burroughs and H.L. Tolman[(1)(2)]

1. Introduction

In order to predict wave conditions adequately over the continental shelf and near land boundaries, a regional model which has higher resolution in grid space and possibly in spectral components is required. The regional model also must calculate rigorously the effects of submarine bottom conditions and any currents which may exist on wave growth, transformation and dissipation. A global-scale wave model usually is designed only to provide the general wave pattern over the deep ocean. It does not provide information accurate enough to describe small-scale, complex wave patterns near the coastal areas.

The Alaska Waters (AKW) regional wave model was designed to fill the needs of the Alaska Region which had requested that the area covered by the Gulf of Alaska (GAK) regional wave model be expanded to include all the waters that surround Alaska rather than just an interior portion of the Gulf of Alaska. The GAK is a second generation[(3)] wave model. As a result, the predicted values over the stormy areas are not as accurate as those of third generation[(4)] wave models which describe these conditions more adequately. The boundary conditions are provided by the NOAA/WAM which is scheduled to be replaced by the NOAA WAVEWATCH III (NWW3) after the new IBM computer is moved to Bowie, Maryland in the late Fall 1999.

The GAK was used for operational forecasting of wave conditions over the Gulf of Alaska since April 1994 (Chao 1995) and was replaced with the AKW in January 2000. The AKW is based on the NWW3 which is described in detail in Technical Procedures Bulletin (TPB) 453 (Chen, Burroughs, and Tolman 1999) and Tolman (1999a, b, and c). The NWW3 provides the boundary conditions to the AKW. More specifically, the AKW accounts for wave dispersion within discrete spectral bins by adding in diffusion terms to the propagation equation (Booij and Holthuijsen 1987); it uses the Chalikov and Belevich (1993) formulation for wave generation and the Tolman and Chalikov (1996) formulation for wave dissipation; it employs a third order finite differencing method with a Total Variance Diminishing limiter to solve wave propagation; its computer code has been optimized to utilize the MPP structure of the new IBM R/S 6000 SP computer; it uses a higher spatial resolution (0.50° x 0.25° rather than 30 n mi x 30 n mi), a larger domain (160°E - 124°W by 45°N - 75°N instead of 155°W. - 132°W by 53°N - 61°N), a higher frequency resolution (25 frequencies in place of 20), and a higher directional resolution (24 directions to replace 12).

Various graphics and text products for the AKW are available at

http://polar.wwb.noaa.gov/waves/.

The following wind and wave parameters are available in GRIB format at the web site above, on Family of Services (FOS), and on AWIPS as GRIB bulletins: H_s, D_m, T_m, peak wave period and direction, wind sea peak period and direction, wind speed and direction, and u- and v-wind components. Note, however, that significant wind sea height, significant swell height, and mean swell period and direction are no longer provided. The peak period and direction replaces the swell period and direction for a large part of the domain.

Spectral text bulletins for the AKW are available at the web site above. These files are in ASCII and are available by anonymous ftp from the directory

ftp://polar.wwb.noaa.gov/pub/waves.

These bulletins will be implemented on AWIPS as soon as headers can be derived for them. The wave guidance will continue to be generated twice daily based on the 0000 and 1200 UTC cycles of the Aviation (AVN) run of the Global Spectral Atmospheric Model but using data supplied by the AKW.

The AKW model has been run since August 1998. In the succeeding sections, the established forecasting system along with the model structure will be described, followed by a comparison of predicted results with buoy data and GAK model output for identical locations. Finally, the strength of the new model (AKW) and the available products and dissemination is presented.

2. Model Description

Regional wave forecasts for Alaska waters are generated at NCEP by using the AKW model. Fields of directional frequency spectra in 24 directions and 25 frequencies are generated at one hour intervals up to 126 hours. The 24 directions begin at 90 degrees to the east and have a directional resolution of 15 degrees. Note that 12 directions were used by the GAK. The 25 frequencies used by the AKW are given by bin in Table 1.

Figure 1 shows the domain of interest and the depth field which is derived from bathymetric data available from the National Geophysical Data Center. Required input wave spectral data for the boundary grid points of the AKW are obtained by linearly interpolating the spectra of neighboring grids of the NWW3. The wind fields driving the model are obtained from the output of NCEP's operational Global Data assimilation System (GDAS) and the aviation cycles (AVN) of the global atmospheric spectral model (Kanamitsu *et al.* 1991 and Caplan *et al.* 1997). The wind fields are constructed directly from spectral coefficients of the lowest sigma level at $0.5^o \times 0.5^o$ longitude and latitude resolution, and are interpolated to the resolution of the wave model grid. They are converted to 10 m winds by using a neutrally stable logarithmic profile. Air and sea temperature data are obtained from the lowest sigma level air temperatures of the AVN model and from the 50km SST analysis provided by NESDIS (updated twice per week) are used in the model wave growth parameterization. Finally, the wave model incorporates a dynamically updated ice coverage field in the region. These data are obtained from NCEP's operational automated passive microwave sea ice concentration analysis (Grumbine 1996; updated daily). Ocean currents are not considered in the model at the present.

The model runs twice daily for the 0000 and 1200 UTC cycles. GDAS wind fields from the previous 12 hours at 3-h intervals (analyses and 3-h forecasts) are used for a 12-h wave hindcast. Winds from the AVN at 3-h intervals out to 126 hours are used to produce wave forecasts up to 126 hours at hourly intervals.

3. Performance Evaluation

The AKW has run on the Cray C90 computer since August 1998. The adequacy of the model has been evaluated by comparing model output of the AKW and the GAK with observed data at NDBC buoys 46001 (56.3^oN, 148.2^oW) and 46003 (51.9^oN, 155.9^oW). Figures 2 (a), (b), and (c) show scatter plots of the significant wave height (H_s) produced by the AKW for +00, +24 and +48 hrs forecasts, respectively, for October 1998. Also shown are the following statistical indices: the mean bias error (bis), root mean square error (rms), correlation coefficient (cor), and scatter index (sci). The total number of data points(ndp) used in the analysis combines the results of both buoys for the 00 and 12 UTC cycle runs. Also presented are scatter plots and statistics for wind speed and direction. Similar results for the GAK are given in Figs. 3 (a), (b), and (c). It should be noted that wind input to the GAK is slightly different from that of the AKW. Wind data used in GAK are interpolated to the wave model grid from GDAS and AVN data on 1^ox1^o grid mesh at 10m height.

Figures 4 (a), (b), and (c) show monthly series of bias, rms and mean wave height for AKW predictions at +00, +24, and +48 hr, respectively, against buoy observations. Similar figures are shown for the GAK in Figs. 5 (a), (b), and (c). It should be mentioned that only three months of concurrent data were available for both models (August-October, 1998). Nevertheless, the results of the comparison show that the AKW's predictions have less statistical error, less scattering and higher correlation with observations than the GAK's.

4. Available Products and Dissemination

The following wind and wave parameters are currently available in GRIB format at

ftp://polar.wwb.noaa.gov/pub/waves,

on Family of Services (FOS), on the dedicated communications line (X.25) to Alaska until it's retired, and on AWIPS out to 72-h as GRIB bulletins: H_s, D_m, T_m, peak wave period and direction, wind sea peak period and direction, wind speed and direction, and u- and v-wind components. Spectral text bulletins are also available on the web at the site above and will be on AWIPS as soon AWIPS headers are assigned.

a. GRIB bulletins

GRIB bulletins are available for use in AWIPS and for transmission on the Numerical Data Service of FOS. Table 2 gives the bulletin headers and their meaning. Bulletins are available at 6-h intervals from 00- through 72-h and will eventually be available at 12-h intervals from 84- through 120-h. Available parameters are H_s, D_m, T_m, peak wave period and direction, wind sea peak wave period and direction, and u and v components of the wind velocity. A 0.50 x 0.25 degree lon./lat. grid is used with a domain from 160^{o}E -124^{o}W and 45^{o}N - 75^{o}N.

b. Alphanumeric spectral messages

Spectral text bulletins are presented for numerous points of the AKW. These bulletins are in ASCII and are available on the INTERNET at present, and, when AWIPS headers are assigned, they will be available to the field on AWIPS. The line length of the table is 130 characters by 100 lines. The header of the table identifies the output location, the generating model and the run date and cycle of the data presented. At the bottom of the table, a legend is printed. The table consists of 8 columns. The first column gives the time of the model results with a day and hour (the corresponding month and year can be deduced from the header information. The second column presents the overall significant wave height (H_s), the number of individual wave fields with a wave height over 0.15 m that could not be tracked in the table (x). Individual wave fields in the spectrum are identified by using a partitioning scheme similar to that of Gerling (1992). In the remaining six columns individual wave fields identified with their wave height (H_s), peak wave period (T_p) and mean wave direction (dir, direction in which waves travel relative to North). Generally, each separate wave field is tracked in its own column. Such tracking, however is not guaranteed to work all the time. An asterisk (*) in a column identifies that the wave field is at least partially under the influence of the local wind, and, therefore, most likely part of the local wind sea. All other wave fields are pure swell.

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Tolman, H.L., 1999c: WAVEWATCH-III version 1.18: Postprocessing using NCAR graphics. *Technical Note No. 168*, Ocean Modeling Branch, NCEP, National Weather Service, NOAA, U.S. Department of Commerce, 9 pp. [Available at http://polar.wwb.noaa.gov/waves/wavewatch/].

1. H. L. Tolman is a UCAR visiting scientist with OMB

2. OMB Contribution No. 171

3. A second generation wave model uses dynamics in wave generation, but the nonlinear energy transfer mechanism is over-simplified, and the wave growth is artificially limited by the Joint North Sea Wave Project (JONSWAP) spectrum (SWAMP Group 1985).

4. A third generation wave model solves the radiative equation by direct integration of all its components without pre-assumed constraints to the spectral shape. Previous models rely (partially) on assumed spectral shapes and parameterizations of the integral effects of the physics of wave growth and decay.

Table 1. The center frequencies and corresponding band widths with center period by frequency bin.

bin number	center frequency (Hz)	frequency band width (Hz)	center period (s)
1	.0418	.00399	23.94
2	.0459	.00439	21.76
3	.0505	.00482	19.79
4	.0556	.00531	17.99
5	.0612	.00584	16.35
6	.0673	.00642	14.87
7	.0740	.00706	13.51
8	.0814	.00777	12.29
9	.0895	.00855	11.17
10	.0985	.00940	10.15
11	.1083	.01034	9.23
12	.1192	.01138	8.39
13	.1311	.01251	7.63
14	.1442	.01376	6.93
15	.1586	.01514	6.30
16	.1745	.01666	5.73
17	.1919	.01832	5.21
18	.2111	.02015	4.74
19	.2322	.02217	4.31
20	.2555	.02438	3.91
21	.2810	.02682	3.56
22	.3091	.02951	3.24
23	.3400	.03246	2.94
24	.3740	.03570	2.67
25	.4114	.03927	2.43

Table 2. WMO GRIB bulletin header descriptors.

T_1	T_2[1]	A_1[2]	A_2	dd	Station id
O	A	N	A	88	KWBJ
	B		C		
	C		E		
	J		G		
	K		I		
	M		J		
	N		K		
	P		L		
	Y		M		
			X		
			N		
			Y		
			O		

Where:

T_1 is the bulletin type descriptor: O - oceanographic.
T_2 is the parameter descriptor, see notes below.
A_1 is the grid and domain descriptor: N - 0.50^o x 0.25^o lon/lat grid over domain from 160E - 124W and 45N - 75N.
A_2 is the forecast hour descriptor, see notes below.
dd is the surface descriptor: 88 - ocean surface.

Notes:

1. Parameter descriptors

A - u-wind component
B - v-wind component
C - Total significant wave height
J - Peak wave period
K - Peak wave direction
M - Peak wind sea period
N - peak wind sea direction
P - D_m
Y - T_m

2. Forecast hour descriptors at 6-h intervals from 0- to 72-h.

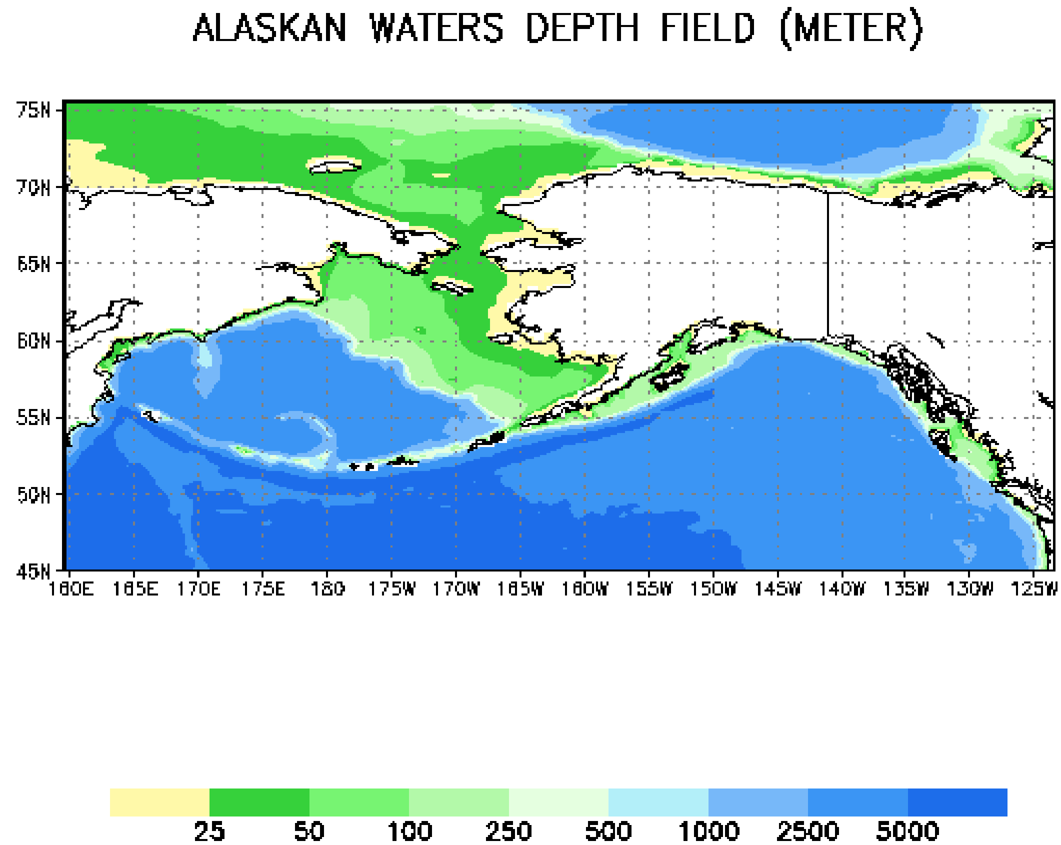

Figure 1. Alaska waters regional wave model domain showing depth in meters.

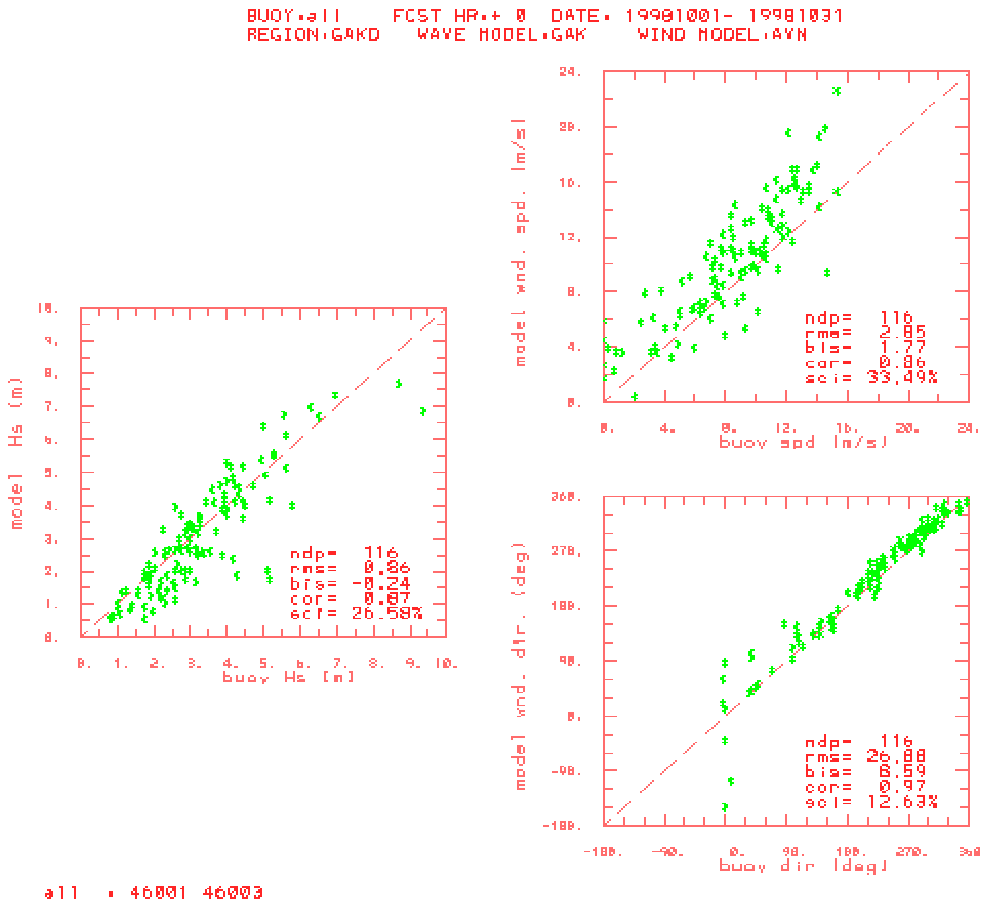

Figure 2a. Scatter plots of significant wave height, wind speed, and wind direction (forcing for wave model) for the AKW regional wave model versus buoys for the month of October 1998 for the 00-h hindcast for both the 0000 and 1200 UTC model cycles combined. Also shown are the mean bias (bis), root mean squared error (rms), correlation coefficient (cor), scatter index (sci), and number of data points (ndp).

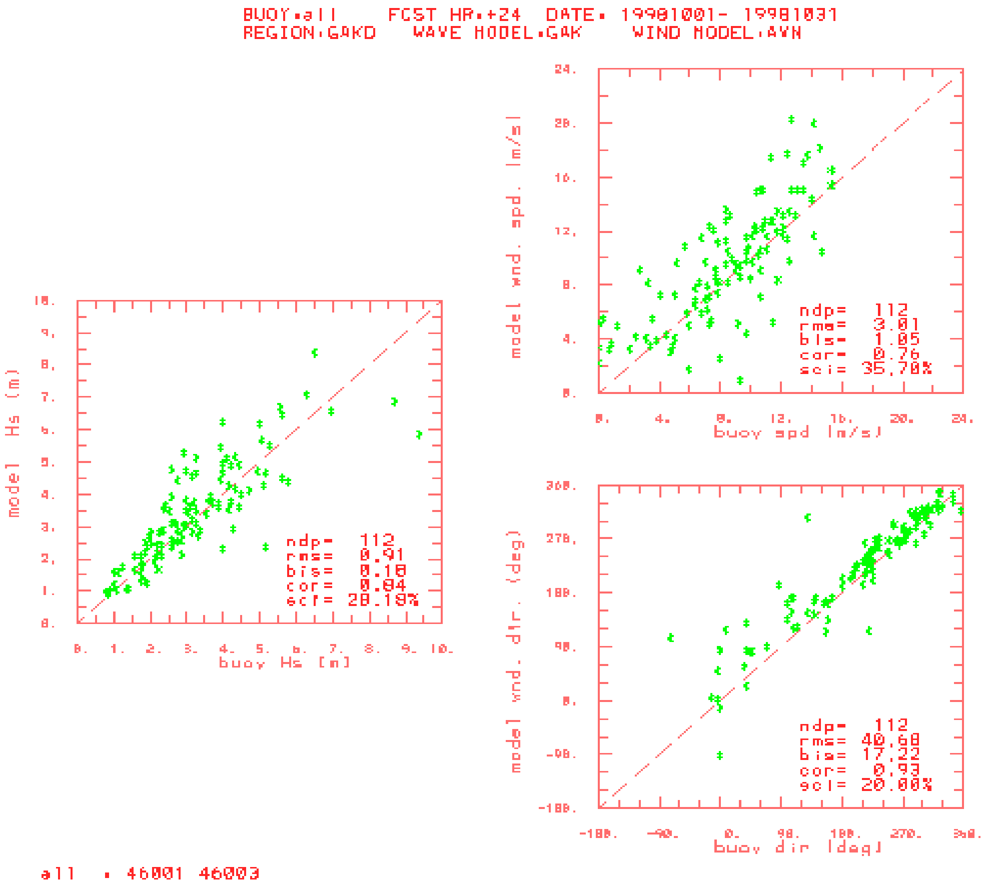

Figure 2b. Same as Fig. 2a except for 24-h forecast.

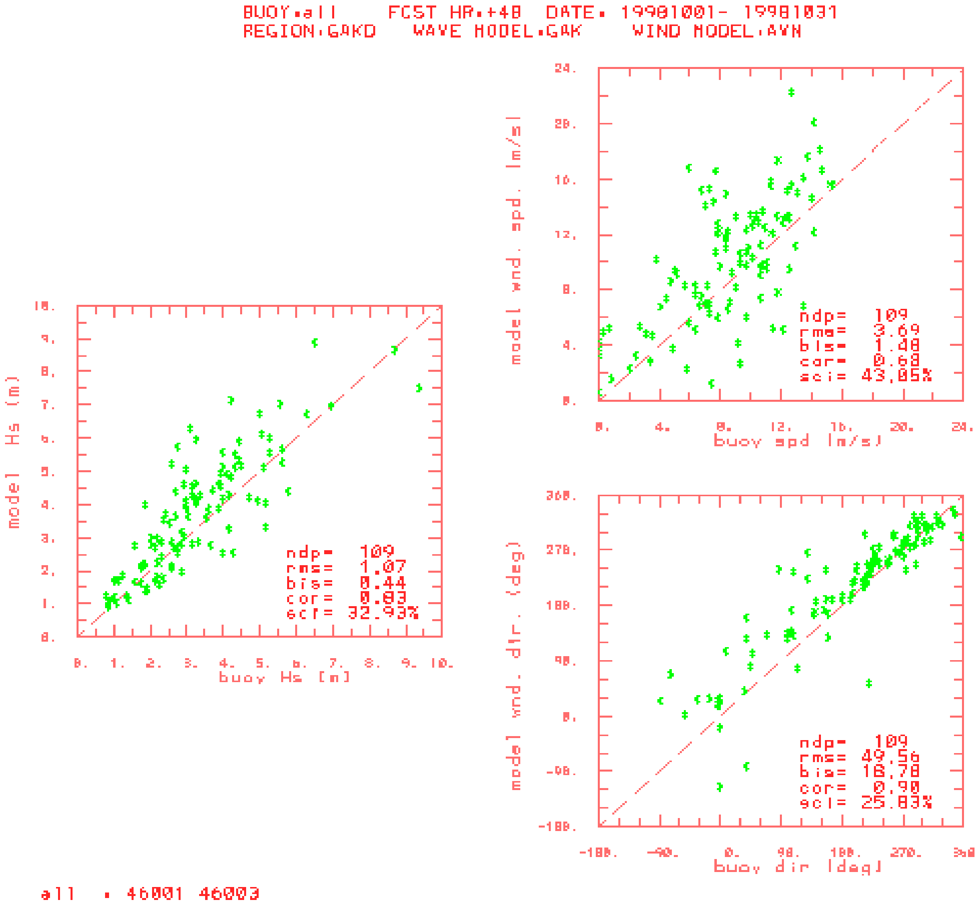

Figure 2c. Same as Fig 2a except for 48-h forecast.

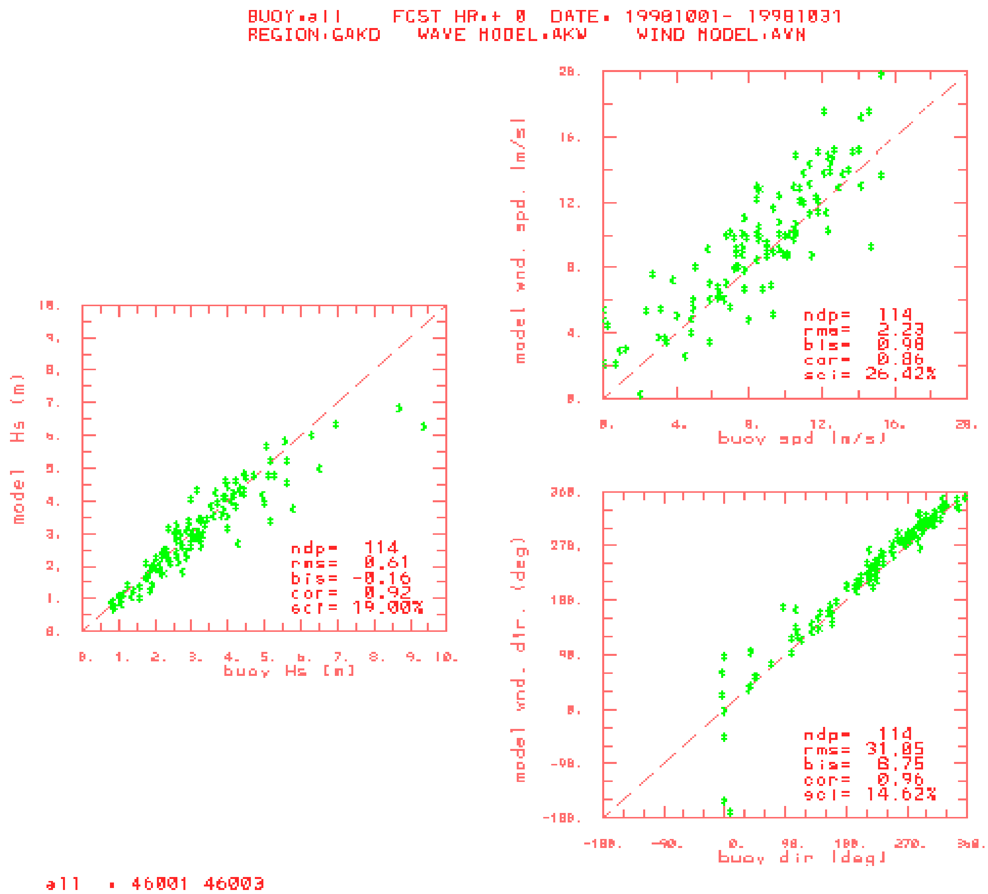

Figure 3a. Same as Fig. 2a except for GAK regional wave model.

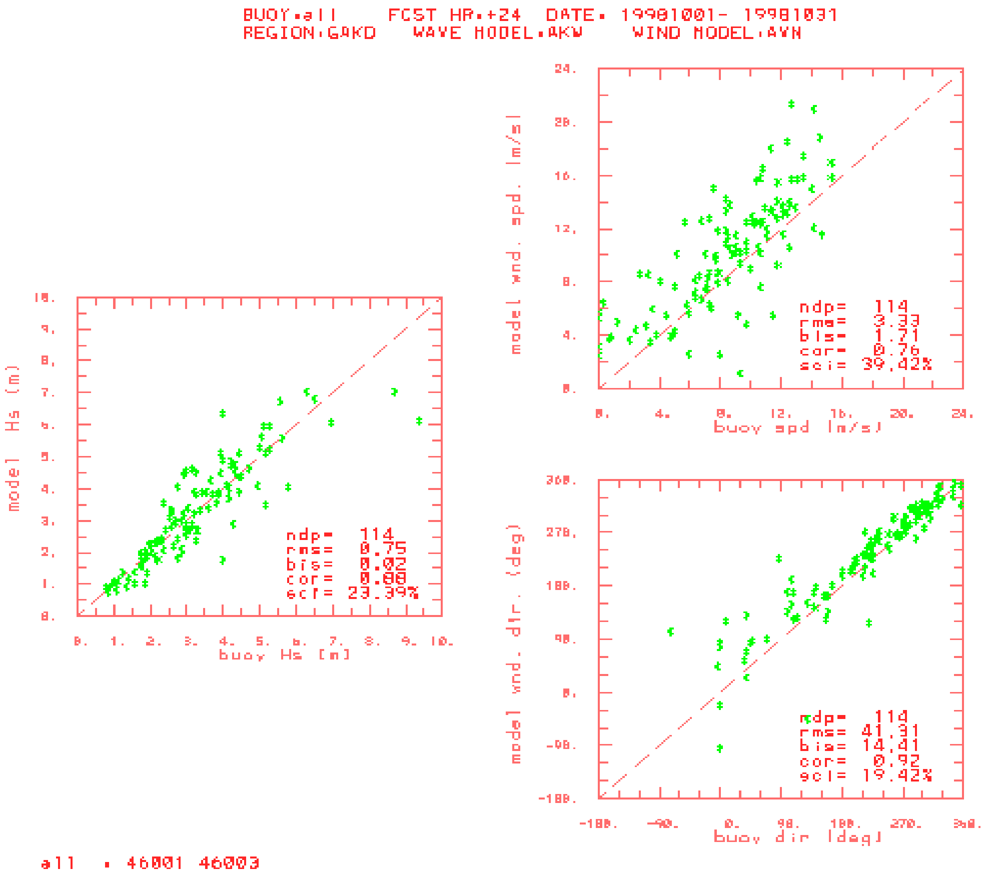

Figure 3b. Same as 3a except for 24-h forecast.

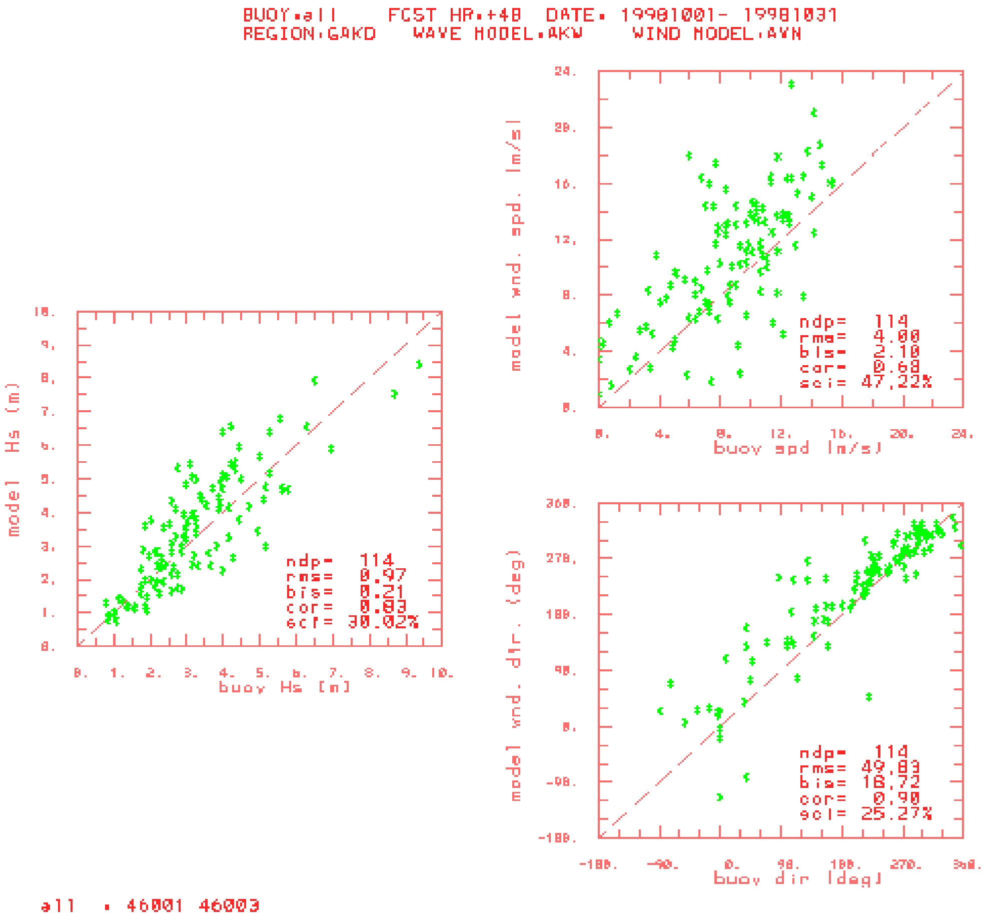

Figure 3c. Same Fig. 3a except for 48-h forecast.

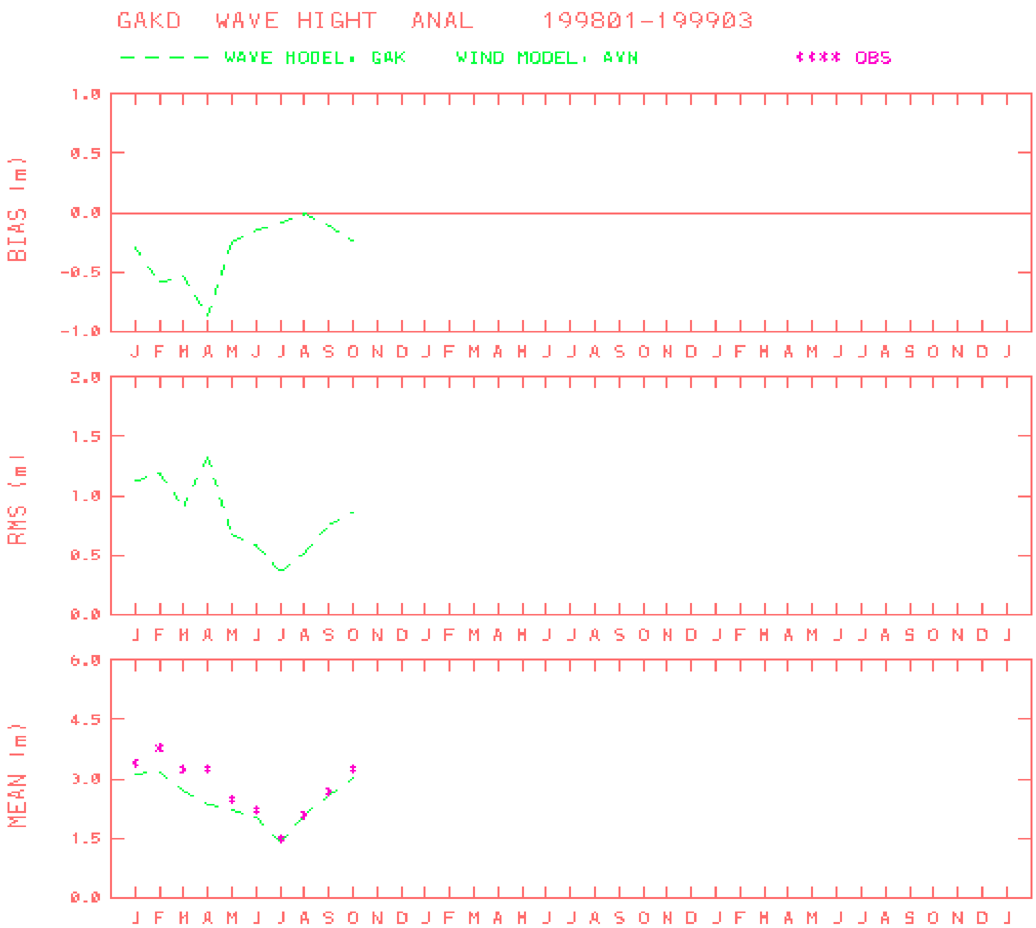

Figure 4a. Time series of bias, rms, and mean for the AKW regional wave model significant wave heights versus buoy significant wave heights for the months of January - October 1998 for the 00-h hindcast for the 0000 and 1200 UTC model cycles combined. The x's on the mean wave height chart represent the mean significant wave height for the buoys.

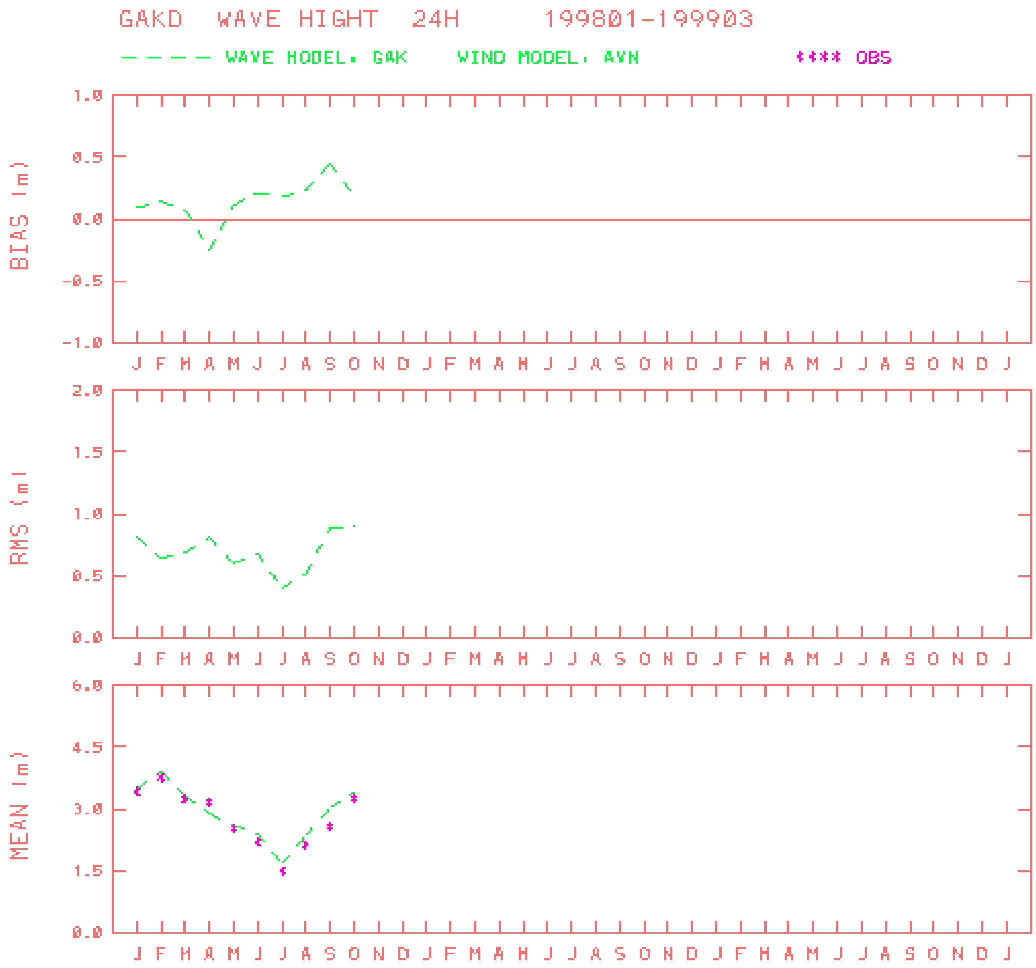

Figure 4b. Same as Fig. 4a except for 24-h forecast.

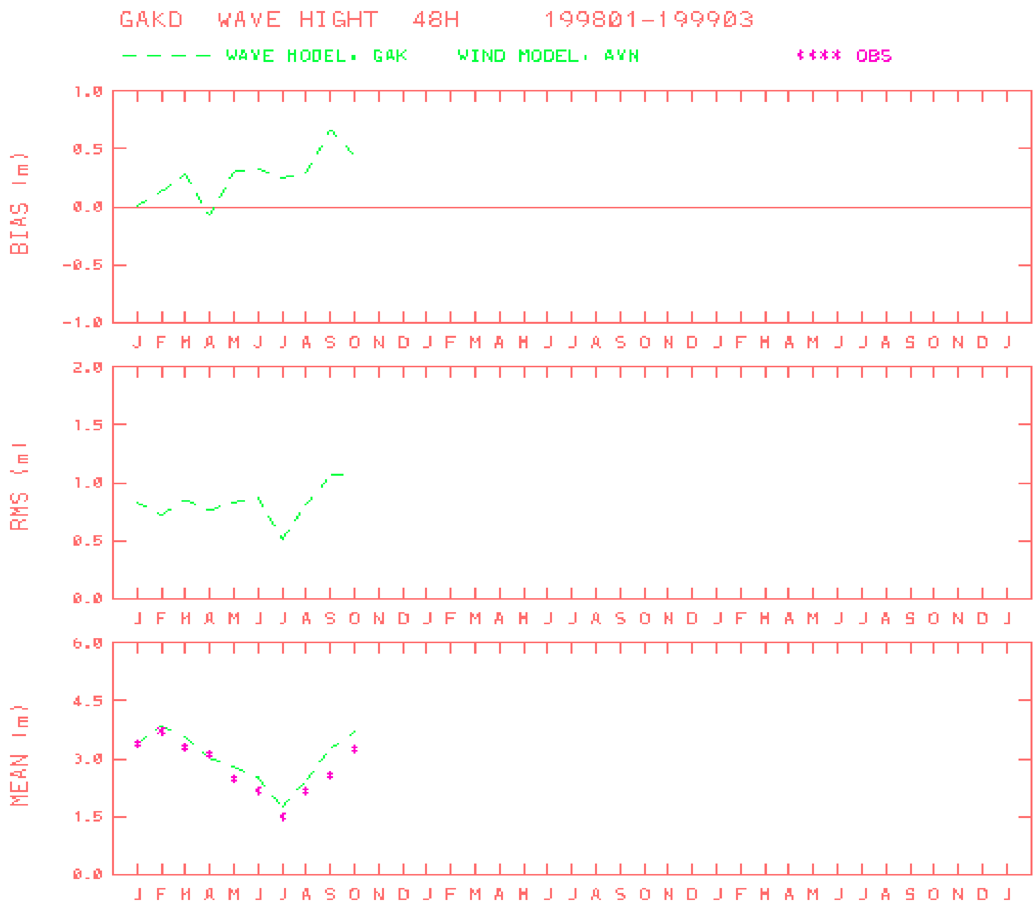

Figure 4c. Same as Fig. 4a except for 48-h forecast.

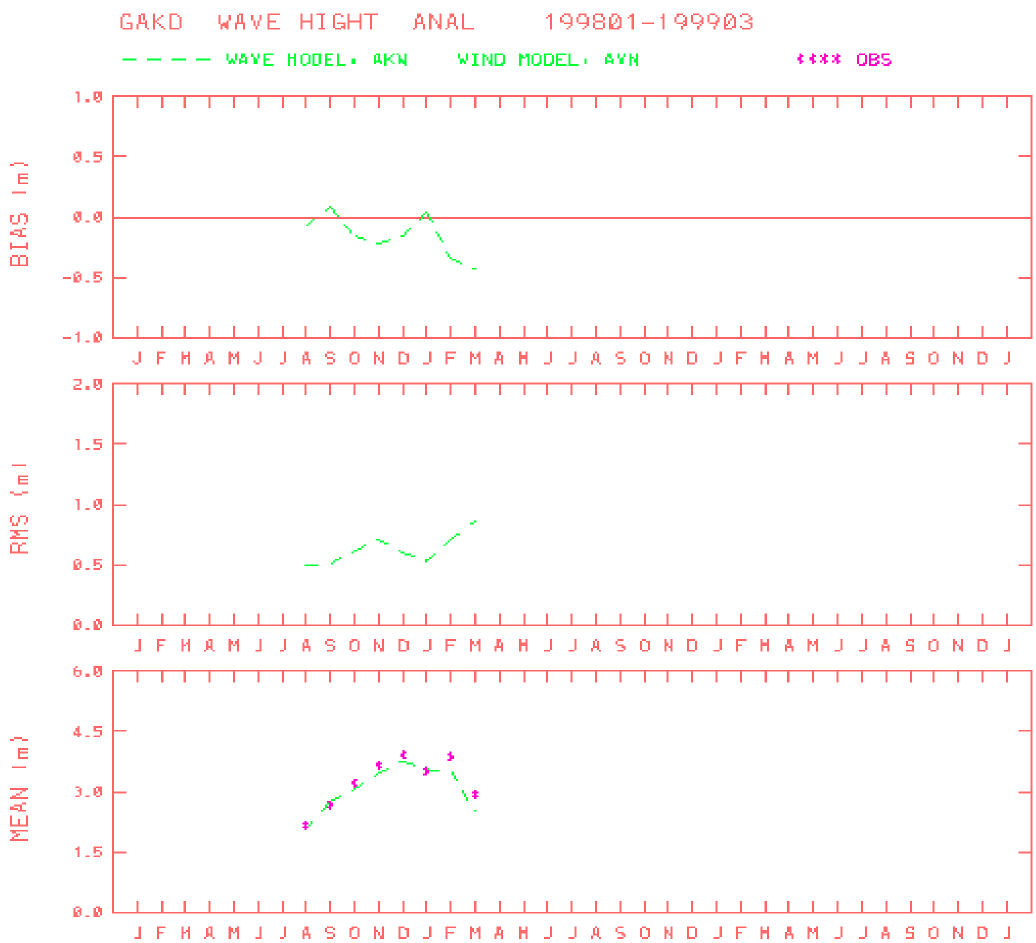

Figure 5a. Same as Fig. 4a except for GAK regional wave model.

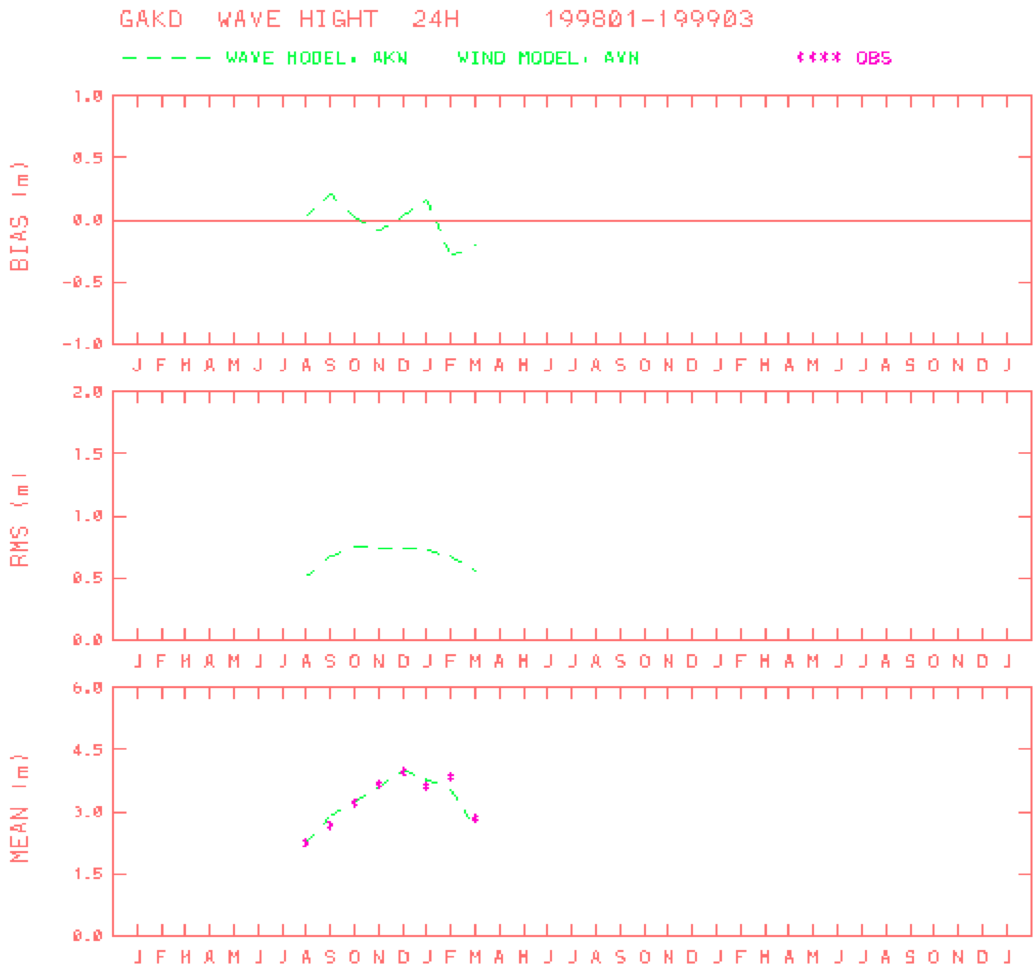

Figure 5b. Same as Fig. 5a except for 24-h forecast.

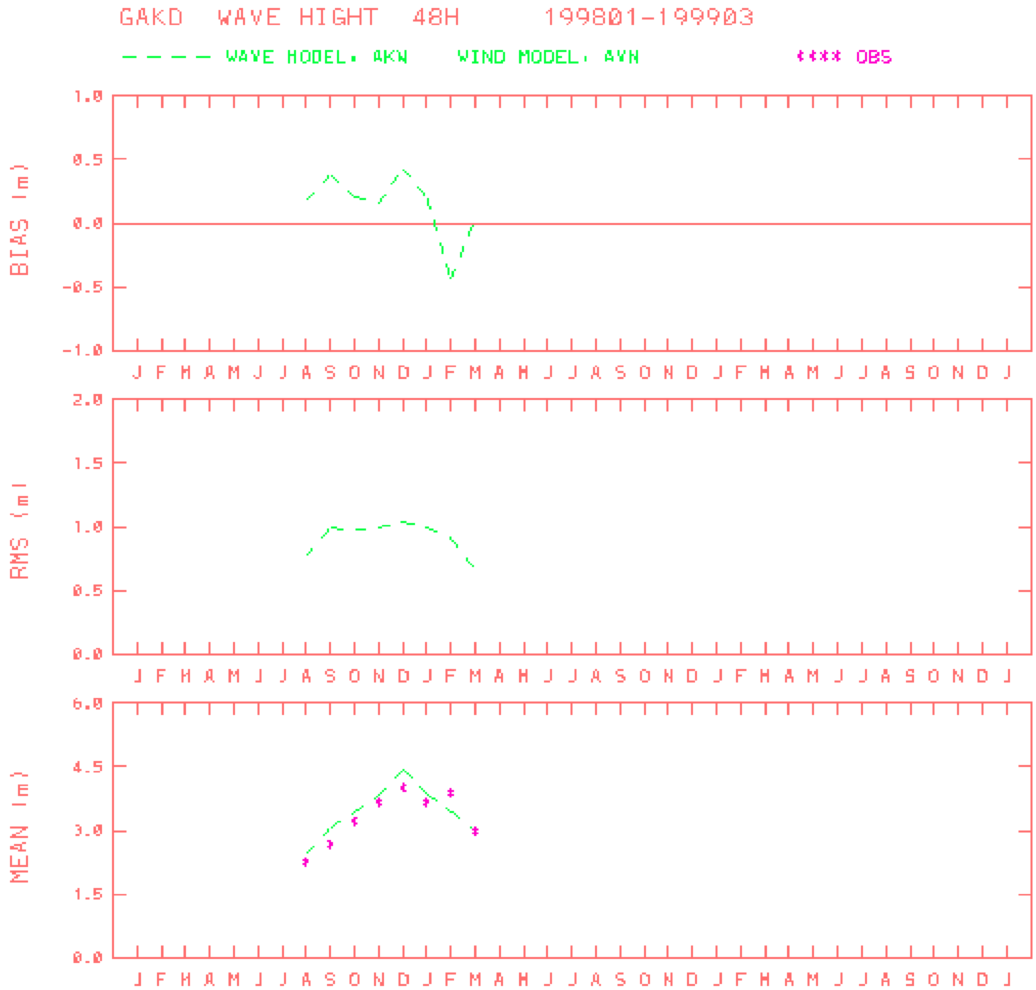

Figure 5c. Same as Fig. 5a except for 48-h forecast.